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Towards Simulation Based Acquisition: RMS Initiatives

Louisa Guise

Sr. Manager Systems Engineer

Raytheon Missile Systems,

Tucson, Arizona

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Simulation at Raytheon Missile Systems

- **RMS uses Modeling and Simulation (M&S) for operations analysis, proposal support, engineering design, integration & test and performance analysis.**
- **Types of M&S include constructive, virtual and live.**
- **Constructive simulations include**
  - **Missile 6 Degree of Freedom (6DOF) or Integrated Flight Simulation (IFS)**
  - **Computer-in-the-Loop (CIL) simulations**
  - **Hardware-in-the-Loop (HWIL) simulations**
  - **System-in-the-Loop (SIL) simulations**
  - **Operational Analysis Models (GOTS and internally developed)**
- **Virtual simulations include**
  - **Wargaming lab**
  - **WINS Center**
- **Live simulations**

Simulation is key to our system design, integration and test

Call to Action: We needed a consistent simulation process

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- **Current RMS is a merging of multiple different legacies including Hughes, TI, Raytheon, General Dynamics and many engineers hired over the last 3 years.**
- **The results of this merging were multiple processes for developing and using simulations.**
- **A Simulation Working Group (SWG) was formed in 1999 to create a common, consistent vision and process for simulation at RMS.**
- **Simulation process is slowly being adopted as new programs start or existing programs reach reasonable injection points.**

Disciplined simulation development required cultural chang

RMS SBA Goals and Benefits

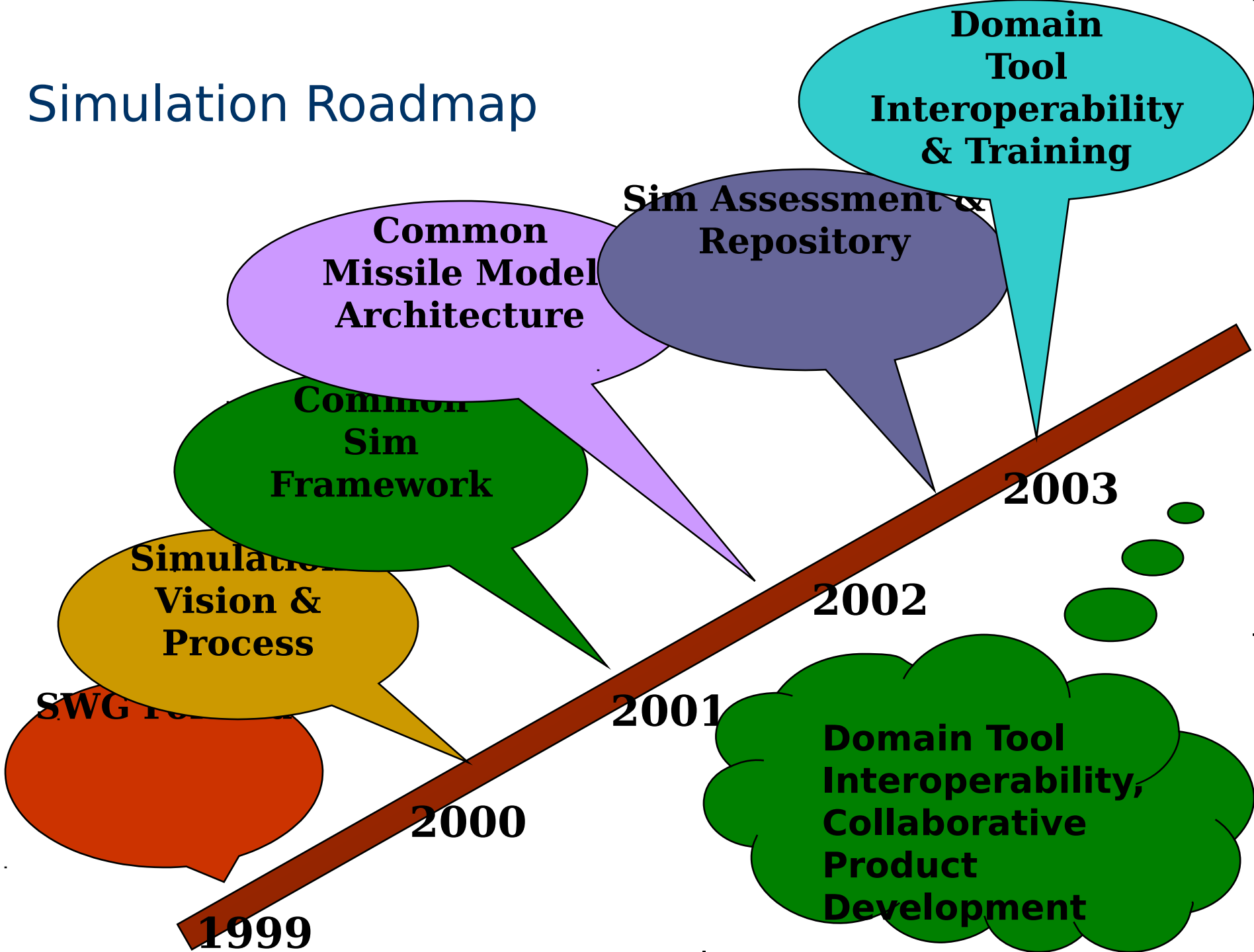
Common Processes

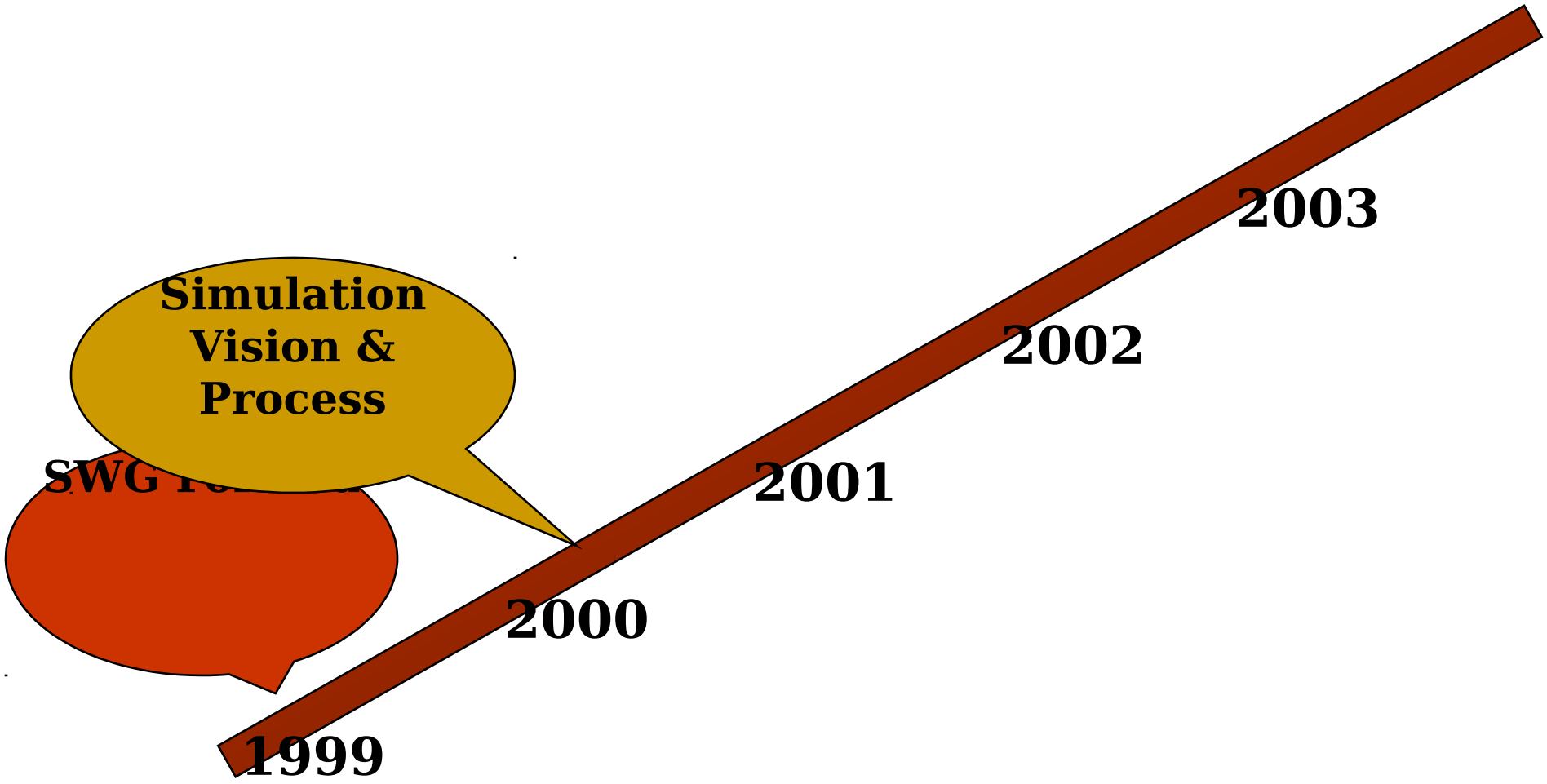
- **Reduces learning curve costs**
- **Reduces cost of development by maximizing re-use**
- **Increases quality / credibility of simulation by establishing good solid engineering**

Reduce redundancies in missile system design, development, integration and test

- **Developing embedded software within simulation reduces redundancies in algorithm design to software implementation process**
- **Using common simulation baseline for proposal, system design, performance evaluation, and integration reduces redundancies in simulation development**
- **Making design tools interoperable with each other and with simulation reduces redundancies in establishing**

Simulation Roadmap




Simulation
Vision &
Process
SWG
1999
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2003

Vision: A simulation process that seamlessly supports Design, Development, Integration, Test and Manufacturing across all programs.

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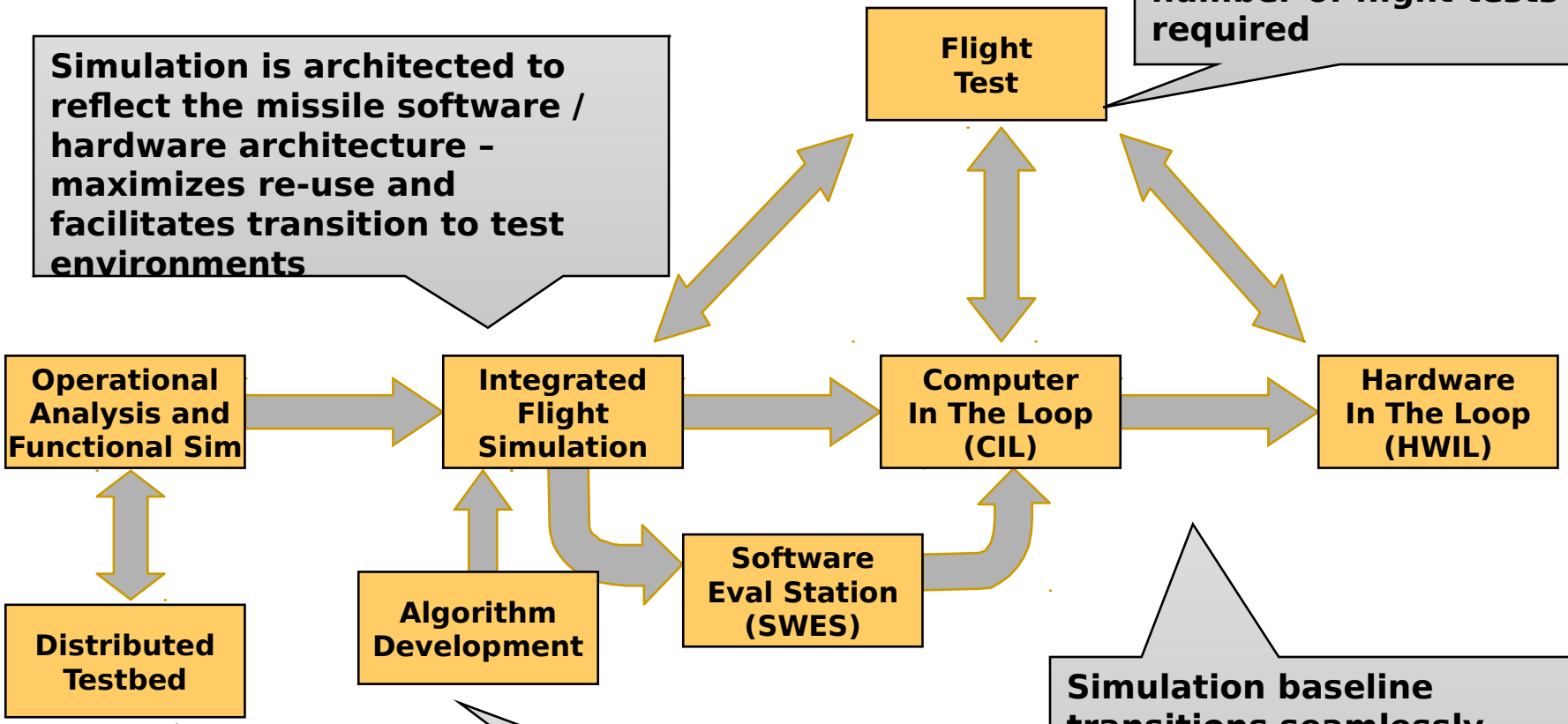
Credible simulation allows for reduction in number of flight tests required
Flight Test
Simulation is architected to reflect the missile software / hardware architecture – maximizes re-use and facilitates transition to test environments
Operational Analysis and Functional Sim
Integrated Flight Simulation
Computer In The Loop (CIL)
Hardware In The Loop (HWIL)
Distributed Testbed
Algorithm Development
Software Eval Station (SWES)
Simulation baseline transitions seamlessly from proposal / requirements tool to design tool to Integration & Test tool.
System testbed establishes top level requirements and CONOPS and interfaces with other BU's and customer facilities. Also serves as baseline for
Algorithm developers develop embedded software within simulation

Simulation Process Ensures Simulation Affordable Credibility

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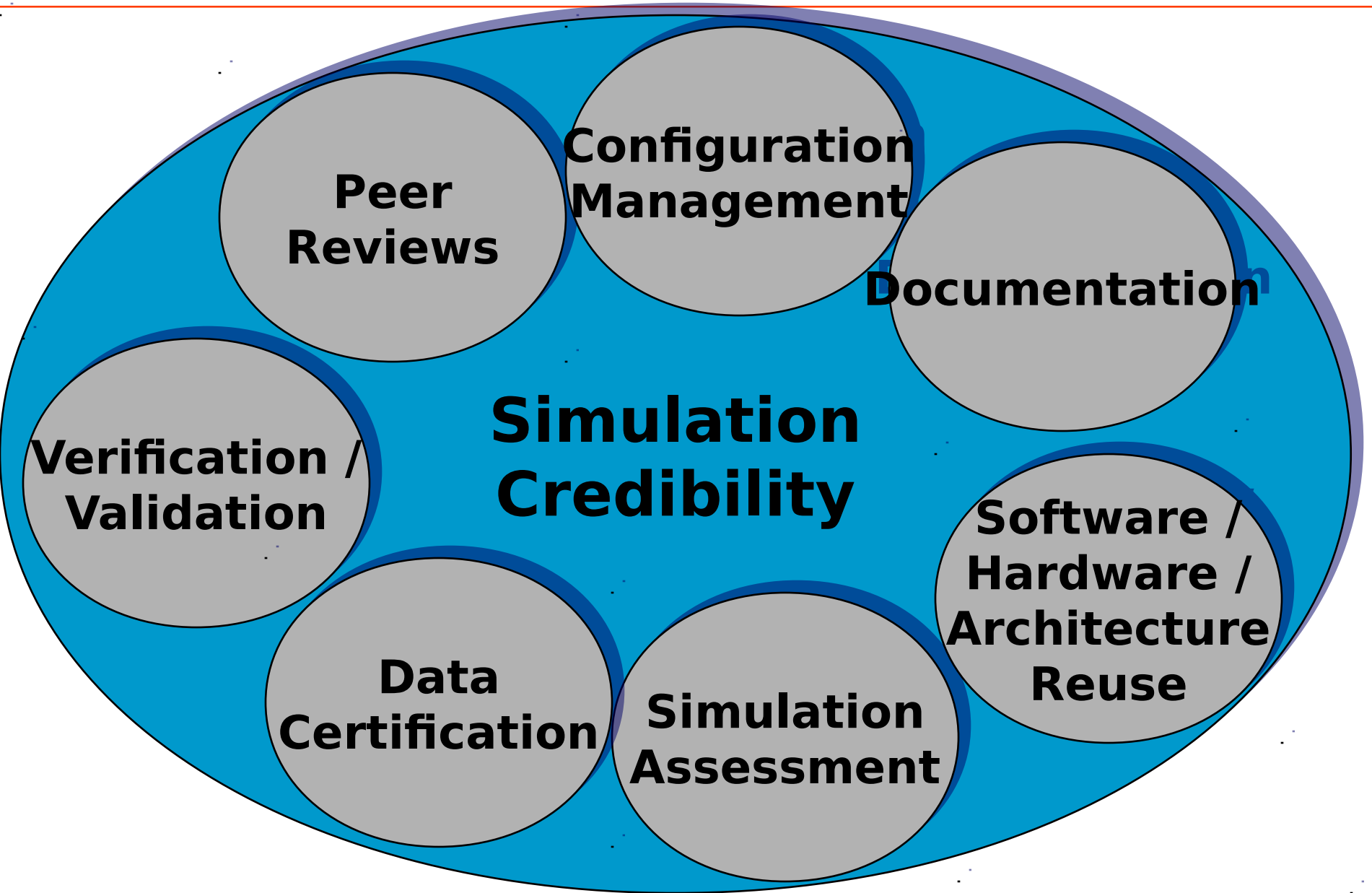

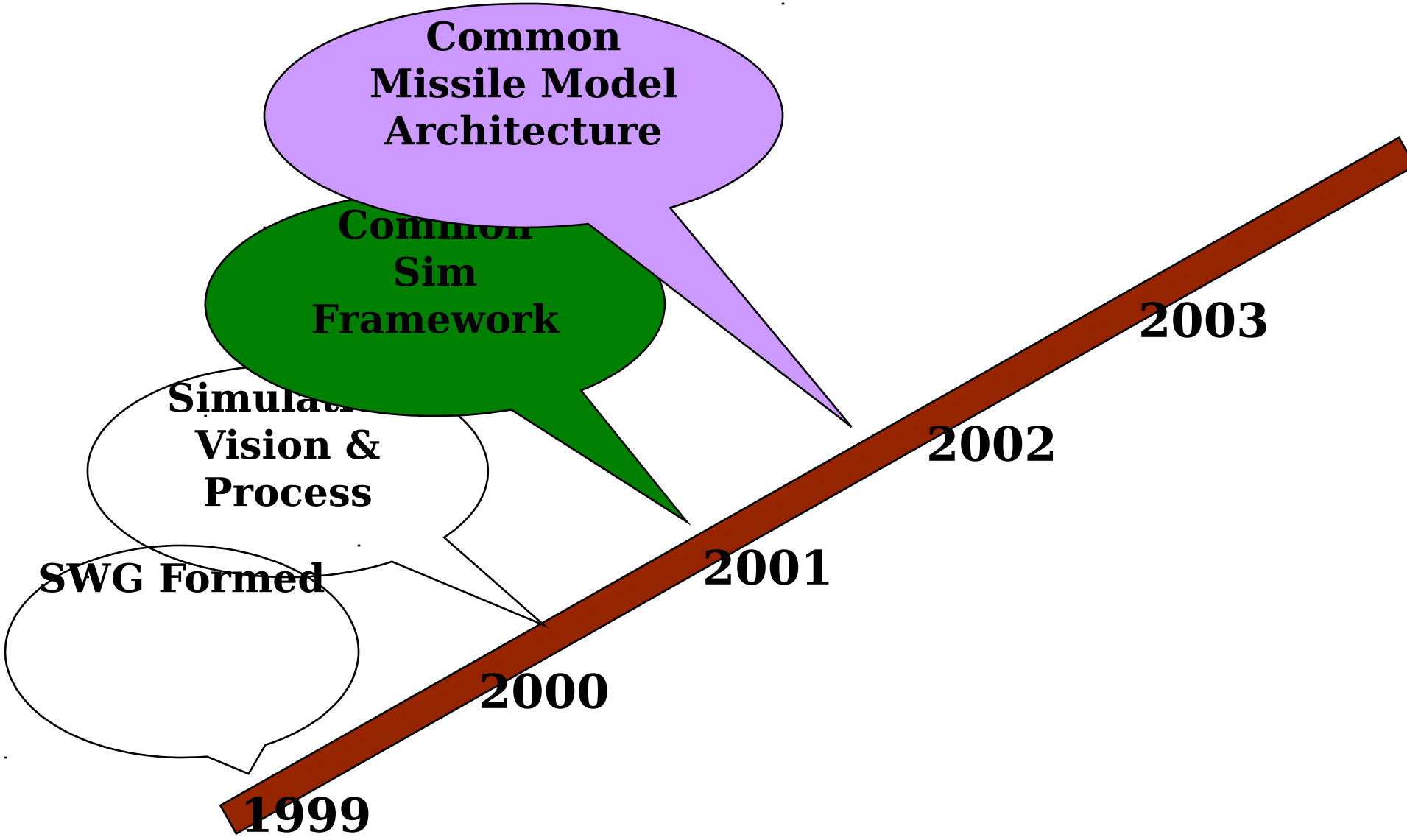
Common
Missile Model
Architecture
Common
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Vision &
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SWG Formed
1999
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2003

Common Simulation Framework and Architecture

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- **RMS has adopted a Common Simulation Framework and Architecture**
- **This facilitates re-use, tool interoperability and improves employee productivity as they transition from one program the next**
- **Simulation framework is the structure within which a simulation “lives” – it is independent upon the application code.**
- **Our missile model architecture defines the objects necessary to represent a missile system and its environment.**
  - **Objects are defined by their interfaces and functionality**
  - **Objects are represented as parent classes within C++**
  - **Objects represent logical decomposition of missile into component objects**

Common Simulation Framework Overview

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- **RMS has adopted the Command Simulation Framework (CSF) as our standard framework.**
- **CSF provides the “glue” needed for simulation development including**
  - **Scheduler**
  - **Integration algorithms and state management**
  - **Inter-object communications**
  - **Mathematics libraries and vector manipulation**
  - **Input / output capability**
  - **Monte Carlo processing control**
  - **Graphical User Interface**

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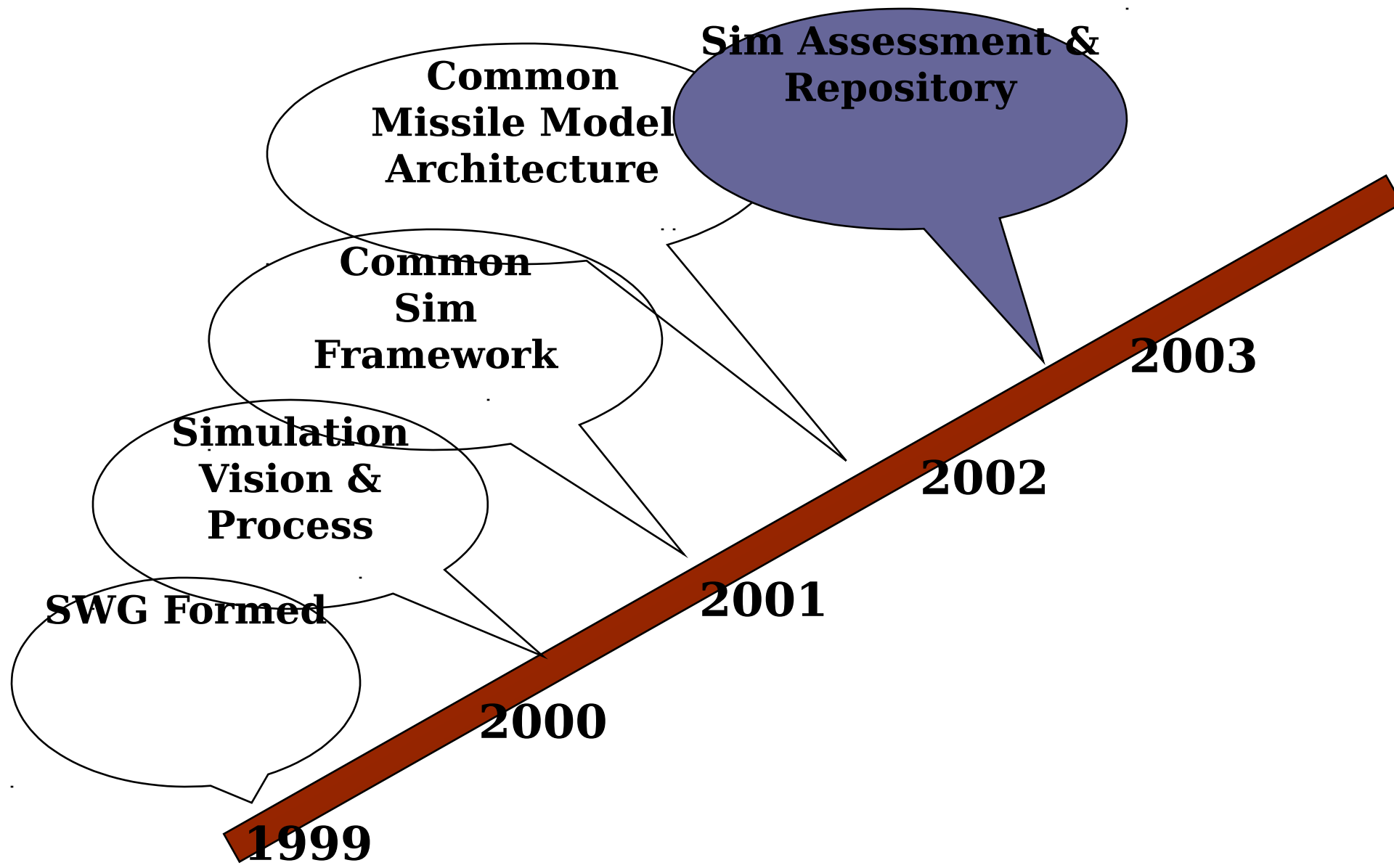
Common Simulation Framework Overview

- **Developed by Army & University of Huntsville**
- **Currently hosted on two platforms**
  - **SGI for lab and real time operation**
  - **Linux for the desktop**
- **Distributed as “Open source”**
  - **All source code is delivered**
  - **All build tools are “public license”**
- **Raytheon participates as a co-developer**
  - **Added some integration and I/O routines desired by programs**
  - **Army shares in adding features and Raytheon leverages off effort**
- **Low overhead**
- **Abstracts complex C++ functionality away from modelers and algorithm developers with use of templates**
- **Developers do not need to know specifics of CSF framework or be experts in C++**

- **CSF Users Group meets every other Wednesday to discuss issues and improvements.**


Sim Assessment &
Repository
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Simulation Assessment

- **The purpose of the simulation assessment tool is to provide a mechanism for programs to determine the level of maturity or credibility of their simulation(s).**
- **The results of the tool are meant to be used by programs to highlight areas that need improvement.**
- **Note that the results need to be interpreted for the phase of the program. For example**
  - **Some programs may be too early in their lifecycle to care about validation, since no validation data may be available.**
  - **Some programs might be so far into their lifecycle that elements of some of the categories may no longer apply.**
- **Assessments may be performed by an independent assessor or as a self-assessment tool**
  - **For independent assessment, assessor will need support from simulation subject matter experts**
- **Anyone with simulation knowledge can perform assessment**

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Assessment Tool Description

- **Tool is composed of 26 questions in 6 key areas**
  - **Development process**
  - **Useability**
  - **Supportability**
  - **Configuration Management**
  - **Verification / Validation Status**
  - **Customer Satisfaction**
- **Each question asks the assessor to rate the simulation's current status as 0 (red), 1 (yellow), 2 (green) or 3 (blue).**
  - **0 = the simulation does not do the topic at all**
  - **3 = simulation nirvana with regard to the topic**
- **The assessor must give objective evidence that the simulation does or has done the topic as defined in the question.**
- **Assessment requires approximately 8 hours (depending upon assessors familiarity with simulation)**
- **After assessment tool has been completed, simulation subject matters make recommendations for areas of improvement**

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Improvement Strategy

- **Improvement strategy should focus on the areas that are of most concern to the program for its phase of development.**
  - **Proposal or pre-SDD program may not care about V&V status, since no data for validation is available. This type of program may care more about Usability.**
  - **SDD program may care more about Development Process and V&V since these programs have more at stake with regard to trusting the simulation results (e.g., high cost of flight tests!)**

Simulation Assessment Provides Indication of Simulation Health

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Numbers in parentheses indicate the weighting factor for each criterion.

Development Process	**1.2**
Model Implementation (5)	1
Testing (5)	1
Quality of Reviews (4)	1
Ease of Code Mod (3)	1
Output Capability (3)	2
Documentation (3)	1
System Platform (2)	2
Programming Standards (2)	1
Developer Training (2)	0
Code Readability (1)	3
Usability	**2.0**
Ease of Use (3)	2
Adequate Output (3)	2
User Training (2)	2
Supportability	**1.5**
Knowledge Base (4)	1
Application Obsolescence (4)	2
Configuration Management	**3.0**
CM Process (5)	3
Verification / Validation Status	**0.5**
V&V Plan (5)	0
Simulation Requirements (4)	1
Simulation Code Correctness (5)	1
Simulation Capability (4)	1
Simulation Validation (5)	0
Simulation Data (5)	0
Customer Satisfaction	**0.0**
Customer Confidence (5)	0
Overall Score	**1.4**

Model, Simulation and Tool Repository Facilitates Re-Use

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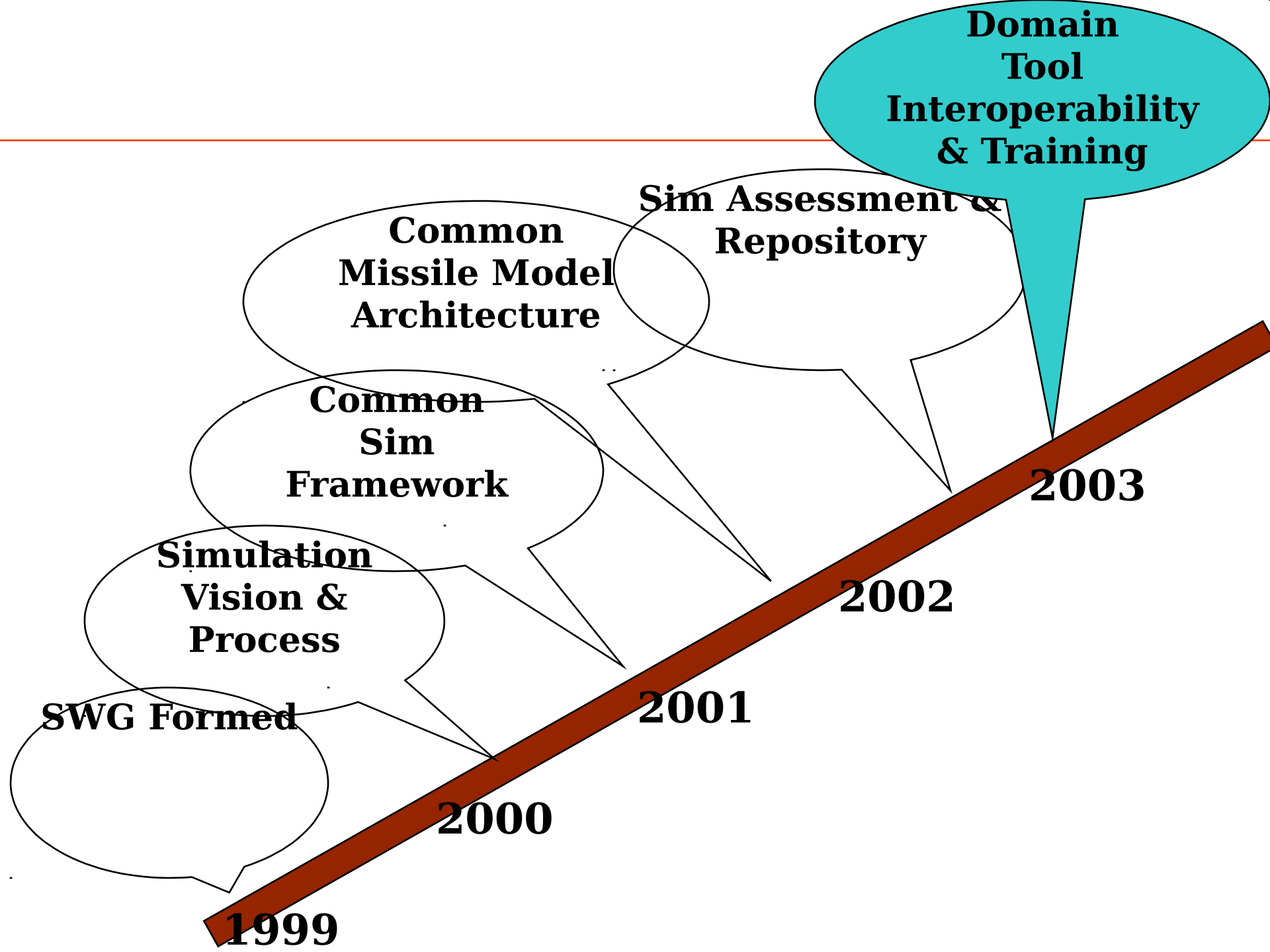
Repository Questions / Comments / Suggestions Please post your questions and comments here by adding a bulletin	74682	06/21/2002	0	
Aerodynamic Models Models that provide missile 6DOF forces and moments	HMTJ6485	08/27/2002	17	
Atmosphere / Environment models Models that establish environmental conditions	74682	06/21/2002	4	
Autopilot Algorithm / Models Algorithms that create missile control commands	HMTJ6246	08/26/2002	4	
BMC3I Models Models of Battle Management, Command, Control & Communications	74682	06/17/2002	1	
Common Simulation Framework Contains the source code, libraries and documentation for CSF	HMT90525	08/26/2002	2	
Computer Processor Models Contains models representing the missile computer processor	74682	04/08/2002	1	
Cueing Sensors Models of sensors providing information to missile system	74682	06/17/2002	1	
EO Environment / Scene Generation Models Contains models depicting EO sensor's environment	lengle	06/17/2002	1	
EO Seeker Models Hardware models for EO seekers	74682	04/08/2002	2	
EO Sensor Signal Processing Algorithms / Models EO Signal processing	74682	04/08/2002	1	
Equations of Motion Missile Dynamics	74682	06/17/2002	8	
Full-Up Simulations Repository for full-up existing simulations	74682	06/17/2002	4	


Domain
Tool
Interoperability
& Training
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Domain Tool Interoperability

- **Effort to ensure that outputs from domain specific tools (e.g., algorithm development tools such as MATLAB) feed the simulations seamlessly**
- **Assumes CSF as the simulation environment although we are working to become “framework agnostic”**
- **Includes explicit processes as well as modifications to tools.**
- **Intent is to connect tools from various disciplines and functional organizations.**

System Design, Integration and Test tools inter-operate seamlessly with CSF based simulations

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Airframe Design

Navigation Design

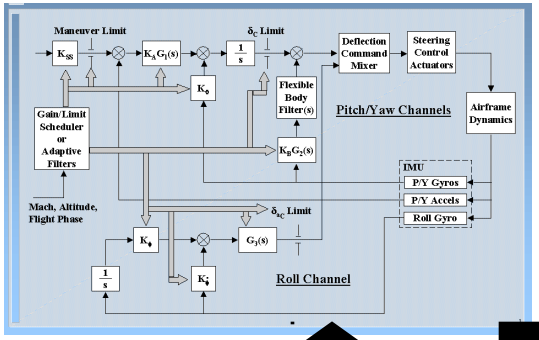
Guidance Design

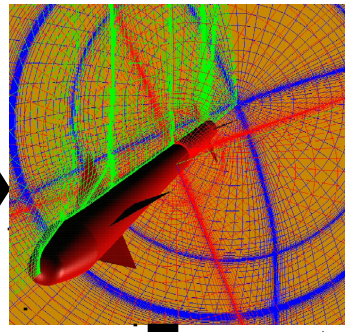
Autopilot Design

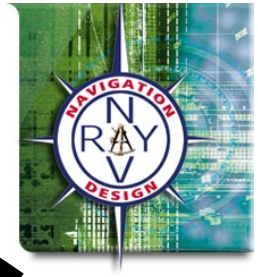
CSF Based Simulation

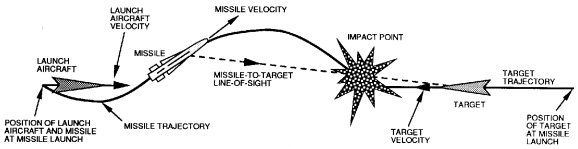
Control System Design

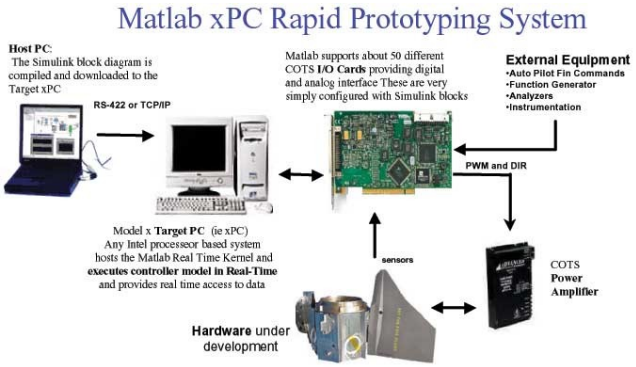
Scene Generation Sensor and Signal Processing

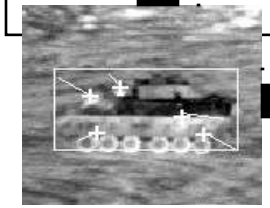


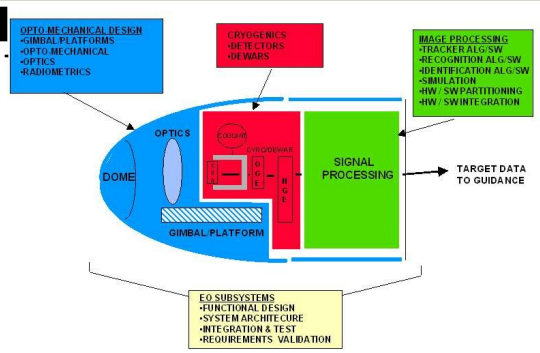







Matlab xPC Rapid Prototyping System
Host PC:
The Simulink block diagram is compiled and downloaded to the Target xPC
RS-422 or TCP/IP
Matlab supports about 50 different COTS I/O Cards providing digital and analog interface These are very simply configured with Simulink blocks
External Equipment
•Auto Pilot Fin Commands
•Function Generator
•Analyzers
•Instrumentation
PWM and DIR
Model x Target PC (ie xPC)
Any Intel processeor based system hosts the Matlab Real Time Kernel and executes controller model in Real-Time and provides real time access to data
sensors
COTS Power Amplifier
Hardware under development





Sim / Tool Interoperability Aerodynamics Example

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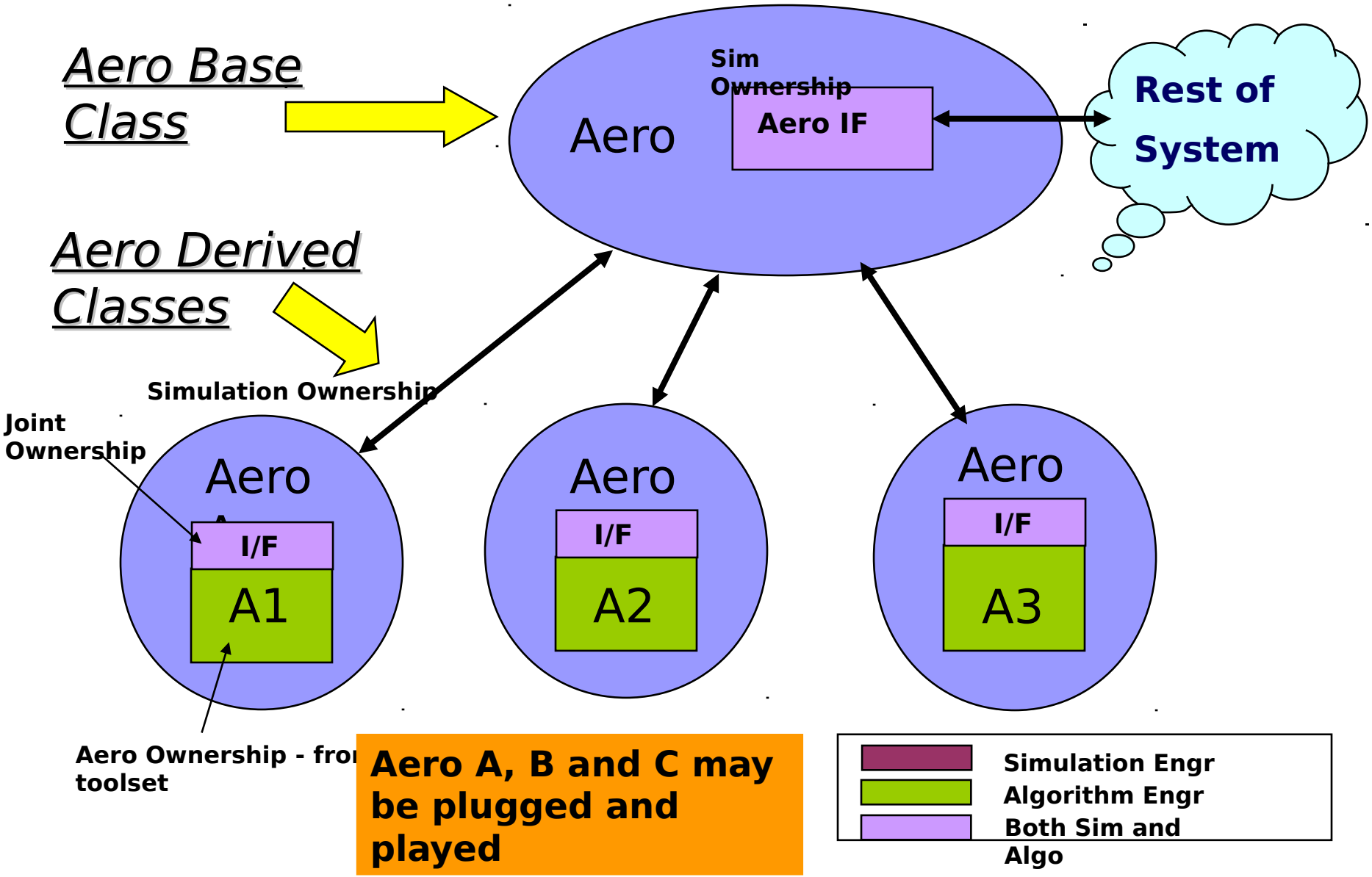
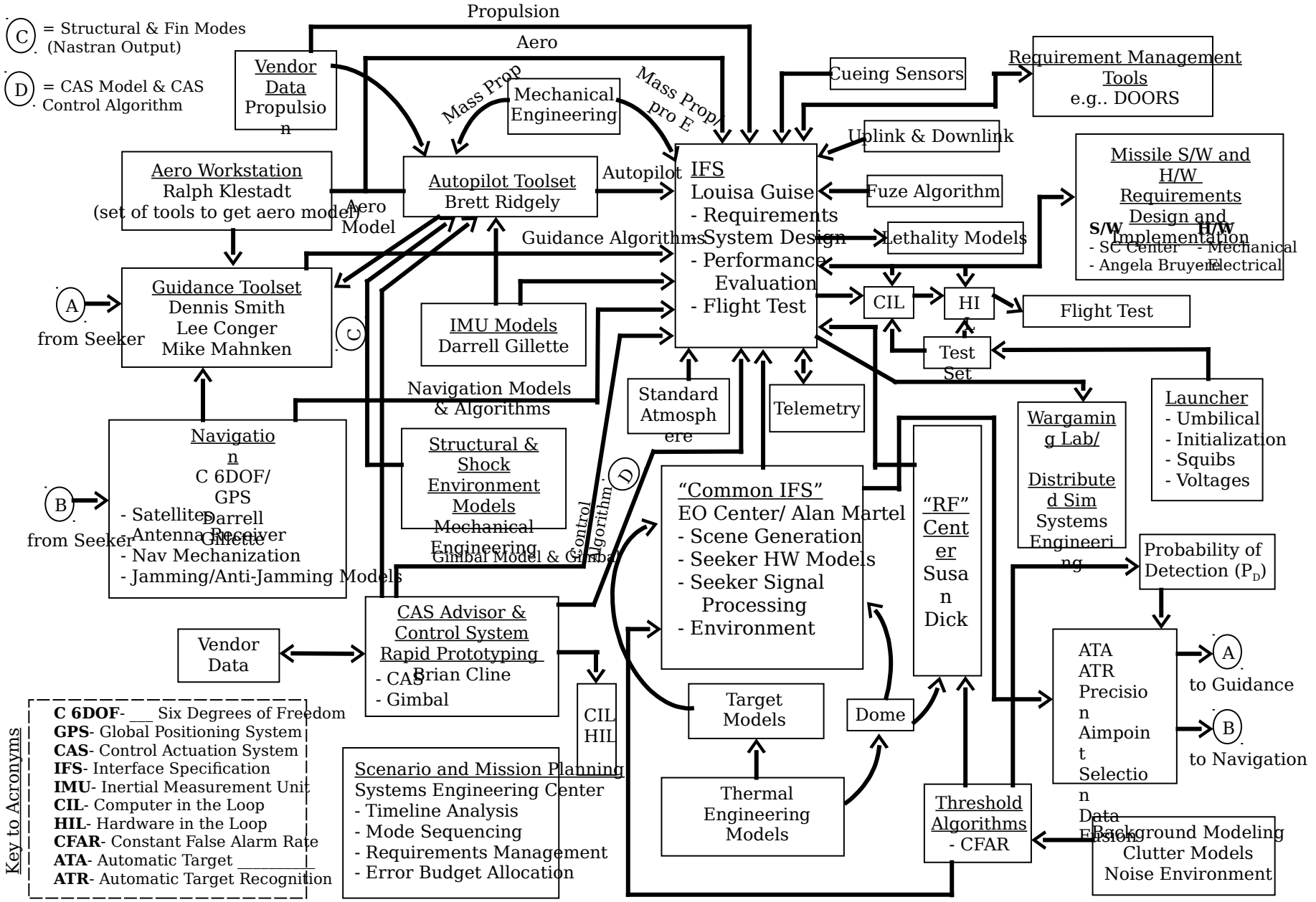


Native Toolsets Feeding Software/Algorithm Development – As Is Process



To Be State: Stakeholders are connected and communicating!

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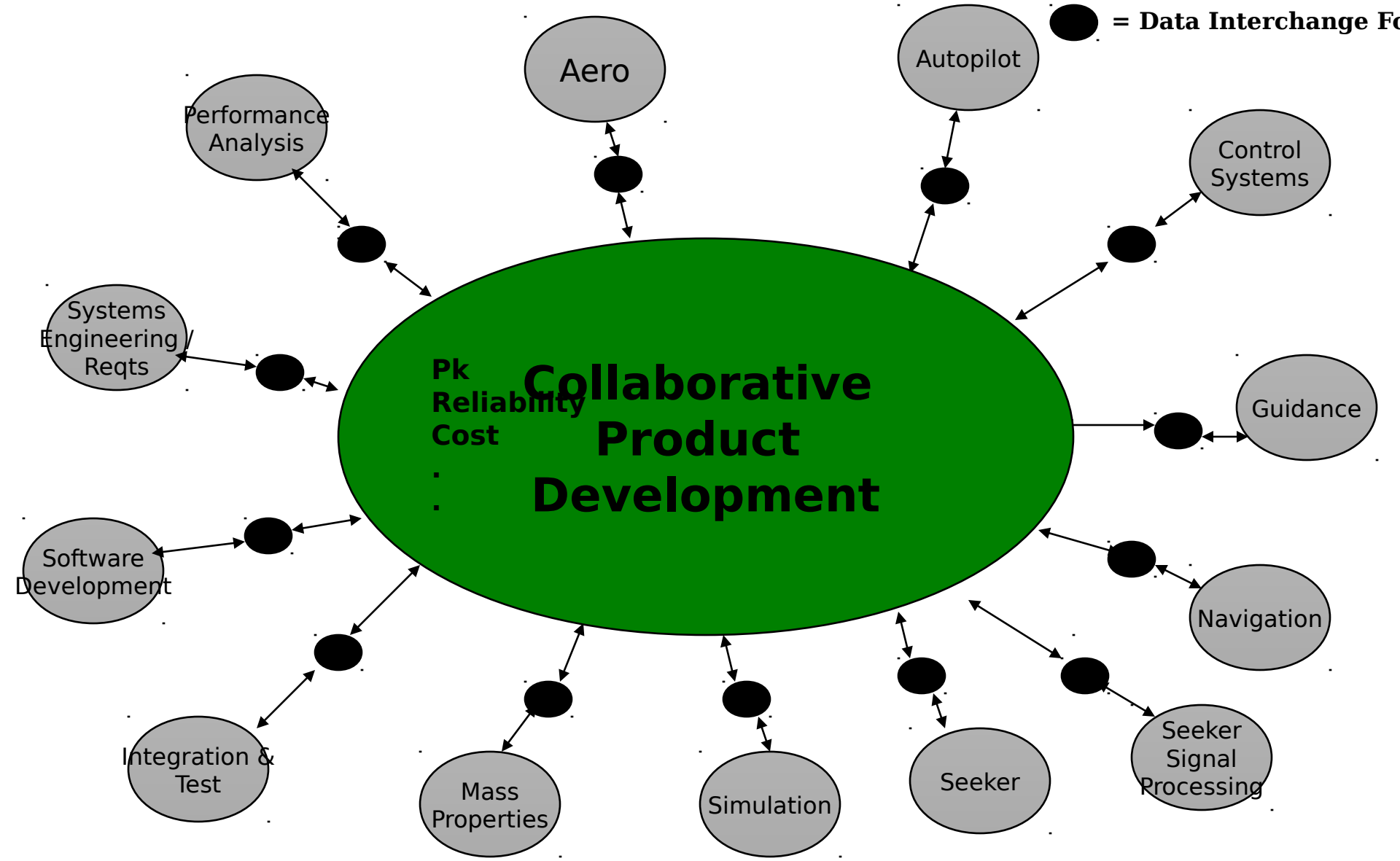

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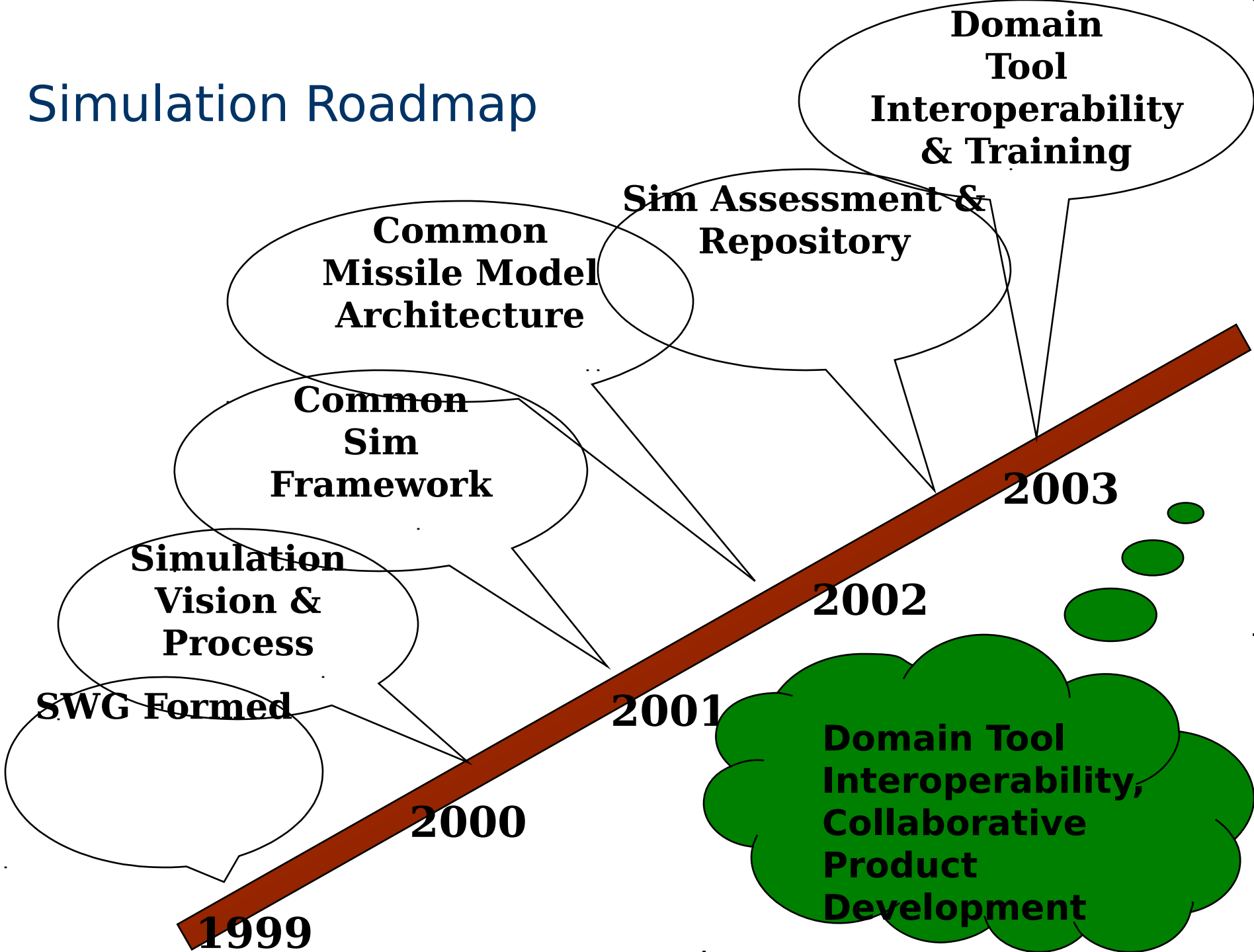
Simulation Training

- **RMS has instituted a Simulation Engineer Certification program.**
- **Three levels of certification: Silver, Gold and Simulation Subject Matter Expert**
- **Each level requires classes and practical experience**
- **Certified Simulation Engineers are recognized with plaques, awards and an award event**

Simulation Roadmap



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The Future

- **We will continue adding tools to our set of interoperable tools to ensure that all algorithms and designs flow as part of a collaborative product development environment.**

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Summary

- **Modeling and Simulation play key roles in system design, integration and test.**
- **RMS has established processes and infrastructure to facilitate *CREDIBLE* simulations that are *EFFICIENT* to develop and *FLEXIBLE* to use in a variety of environments**